Embedded Design of Pilot Multi-physiological Parameter Acquisition Module

Aidong Liu[a], Qun Yu[b]

College of Naval Air Defense Engineering, Naval Air University, Yantai, Shandong 264001, China

[a]1053640261@qq.com, [b]yuqunfish@126.com

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Abstract: Aiming at the requirements of wearable devices such as miniaturization, low power consumption and high precision, this paper analyzes the characteristics of pilots' flying mission in the air, and designs the pilot's multi-physiological parameter acquisition system. The system mainly consists of ADS1292R, LMT70, LIS2DW12 and other high-precision data sampling devices, STM32L476 low-power microprocessor and DA14580 low-power Bluetooth transmission module. According to the characteristics of the pilot, the power consumption of the system is managed, so that the overall power consumption of the system is smaller, and the data of the three days before and after the task can be collected and recorded at one time and then transmitted. The design of pilot physiological data acquisition system can effectively extract the physiological parameters of pilots, such as ECG, respiration, body temperature and overload. It is of great significance to guide pilots' health management and flight training.

1. Introduction

The physical state of the pilot is an important factor in determining whether the flight task can be completed and the quality is completed, so it is of great significance to monitor the physical state of the pilot in the execution of the mission. The physiological state monitoring before the flight can timely find the health problem existing in the pilot, thereby reducing the probability of an accident. The post-flight physiological state monitoring helps to find out whether the flight mission will have a subsequent impact on the pilot. There is a need for a long time physiological monitoring of the pilot. As the pilot is in a mission, the spirit must be hit and should be as little as possible, so the monitoring device for the pilot's physiological sign data needs to be more streamlined and has higher stability and safety. A low-power multi-physiological parameter acquisition front-end is designed to monitor the contradiction between low power consumption and high precision of the equipment, and to design a low-power multi-physiological parameter acquisition front end.

2. System design

The front end of the designed pilot physiological parameter record is shown in figure 1. The main purpose of this monitoring module is to monitor the physiological state of the pilot during flight and before and after flight for up to 3 days, in which ECG signals are the main parameters, such as respiration, body temperature and acceleration, and the collected data are stored on the storage module and exported by the wireless transmission module at the right time. The main objectives of this design are low power consumption, miniaturization design and portability. The system is mainly composed of main control module, acquisition module, storage module, power module and wireless transmission module, like this is shown in Fig.1.

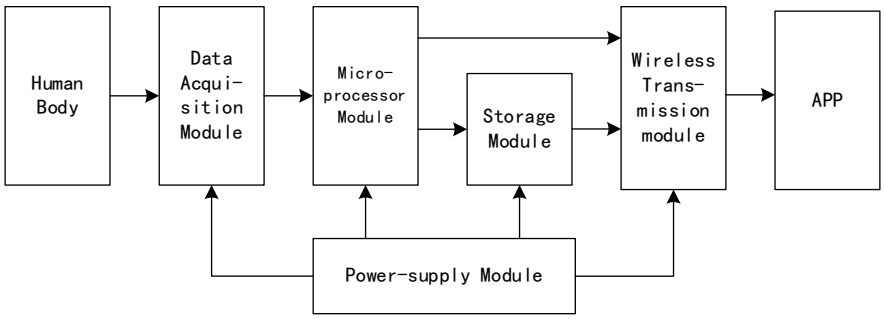

Figure 1. System composition

3. Hardware design

3.1 MCU

The master control module selects STM32L476 as a micro-controller, which is the L4 series of the STM32 series of the Italian-French semiconductor company, and has the performance of ultra-low power consumption and the processing power of the non-custom. [1] The core of the STM32L476 for this design is the ARM Cortex M4, up to 80MHz, and has built-in high-speed memory, up to 1MB of flash and 128 KB of SRAM. The chip also has a rich peripheral interface to meet the demand for multi-sensor measurement. [6] The power consumption of STM32L476 in the operating mode is 100μA/MHz, and a voltage of 1.05-1.32V is supplied to the VDD12 port through an external SMPS, and the internal LDO can be bypassed to drive the V_{CORE} directly, and the power consumption is reduced to 40μA/MHz.

3.2 ECG and respiration data acquisition module

The physical and psychological burden of the pilot's high-strength mission will have a certain impact on the pilot, and the load on the heart is great, so it is important to focus on the health of the heart. ECG monitoring is a common means of monitoring heart activity, the principle of which is that the bioelectricity of the heart itself changes through the conductive tissue around the heart and the body fluid, reflecting the regular electrical changes on the skin of the human body. In order to reduce the impact on the pilot while reducing the power consumption of the device, the less the number of pilots should be, the better the two-lead is selected here.

The monitoring of respiration is also a common physiological monitoring index. For the monitoring of the respiration, the commonly used methods include the monitoring of the nasal airflow, the impedance plethysmography, and the like. The method for monitoring the nasal flow of the mouth requires the measurement of the amount of gas in and out of the gas through the sensor under the nose to derive the respiration, which is not suitable for portable measurement. The design adopts the impedance volume method to monitor the respiratory signal, that is, by adding a high-frequency constant-current source to measure the change of the impedance caused by the change of the volume of the chest cavity when the person is breathing, thereby realizing the monitoring of the respiration.

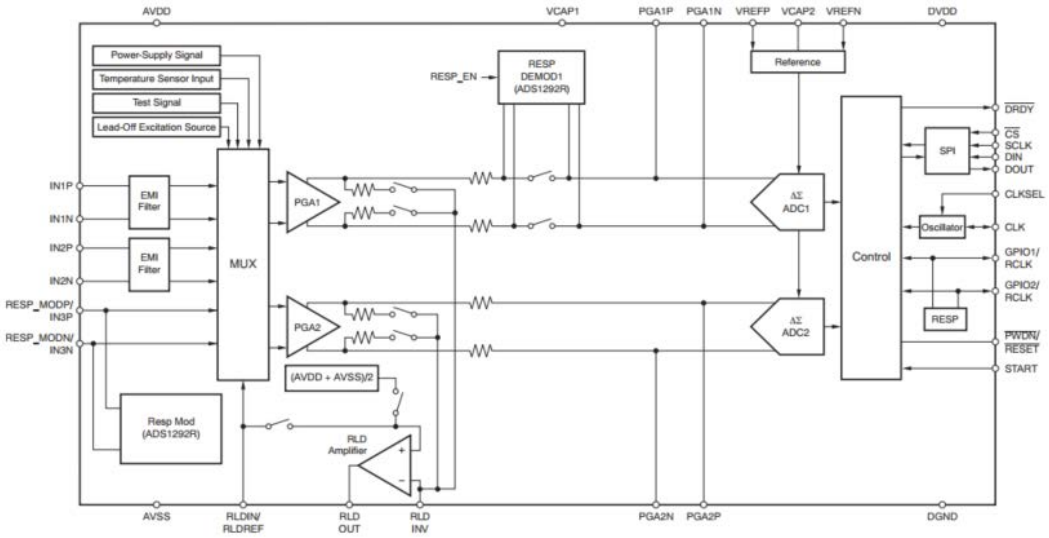

Figure 2. ADS1292R

The ECG respiration signal acquisition module selects the ADS1292R of TI Company. The module has two 24-bit high-resolution ADCs and two low-noise programmable gain amplifiers, which integrate the components required for ECG acquisition and respiration acquisition. [2] The power consumption of each channel is only 335μW, and the two circuits do not add up to 1mW. The common-mode rejection ratio of 105 dB can also provide higher anti-interference capability to the acquisition signal. The built-in lead-off detection and right leg drive circuit of the chip can better detect the electrocardiosignal, and the inside of the Ads1292r integrates the respiratory impedance measurement module, so that the high-frequency square wave for respiration measurement can be provided with two selectable frequencies of 32k and 64k, and the trouble of the external driving circuit is saved. In the case of electric and respiratory multiplexing, since only one channel has a demodulation module for respiration detection, the respiration signal is introduced from the channel 1 and the electrocardiosignal is introduced from the channel 2. The signal is first passed through the EMI electronic filter circuit and then amplified by the PGA. The size of the chip is 5mm * 5mm, and the system can meet the requirement of miniaturization.

3.3 Temperature data acquisition module

The relatively constant temperature of human body is one of the important conditions to maintain the normal life activity of human body. The heat production and heat dissipation of the body are regulated by the nerve center. Many diseases can make the normal regulation of body temperature functional disorder and make the body temperature change. On the contrary, when the body temperature is too high, it will also have an impact on other physiological functions of the human body, resulting in dizziness, shock and other symptoms, serious sequelae. Therefore, body temperature monitoring is of great significance for the diagnosis and c treatment of diseases.

The temperature acquisition module adopts the analog digital sensor LMT70, of TI Company. The chip has the characteristics of high precision and low power consumption. Take the armpit as an example, the normal temperature is 36.0 ≤ 37.3℃, which can reach 41℃ or more when the fever occurs, and it will be below 35℃ when the body temperature is too low. The precision of LMT70 of TI Company can reach ±0.05℃ in the range of 20℃ to 42℃.

3.4 Acceleration Data Acquisition Module

When monitoring the physiological state of pilots, overload value is also an important index. The ratio of aerodynamics and engine thrust acting on aircraft to aircraft gravity is called aircraft overload. The tolerance of different people to acceleration is different. The overload value that fighter pilots can bear through training can reach 8 ≤ 9G, and that of stunt pilots can reach 10g. Exceeding affordability may lead to flight accidents. By measuring the acceleration in flight, the

pilot can master the overload value of the pilot in flight and the operation in daily life and training, and then help to analyze the causes of the physiological changes of the pilot.

This design uses the Lis2dw12 produced by the Italian-French semiconductor as the acceleration sensor. [5] The Lis2dw12 is an ultra-low power, 2-axis acceleration sensor with extremely high measurement accuracy, low noise mode, and optional low power mode. The standby current is only 50nA, with a low power mode operating current of 380nA at a 1.6Hz data rate output.

3.5 storage module

The data of three days are recorded, and the amount of data is very large, so it is necessary to compress the ECG and respiratory data in order to reduce the space needed for storage. To ECG signal: 500 x 24 x 3 x 24 x 3600 / 8 / 388MB. Similarly, the amount of data collected by other physiological parameters is shown in Table 1.

Table.1. Amount of data of physiological parameters

Acquiring content	IC	Sampling rate (SPS)	Sampling bits (bit)	Data size (MB)
ECG	ADS1292R	500	24	388
Respiration	ADS1292R	125	24	97
Temperature	LMT70	12.5	12	5
Acceleration	LIS2DW12	12.5	12	15

It can be seen that the amount of ECG and respiratory signals is very large. Considering the need for miniaturization and low power consumption of the system, ECG and respiratory signals need to be compressed. The compression algorithm with compression ratio of 5 is proposed, then the storage space of ECG and respiratory signals is 78MB and 20MB, respectively, and the total amount of data is 118MB. Therefore, the NAND Flash memory W25N01GV with total capacity of 128MB is selected as the external storage space.

3.6 Wireless Transmission Module

The Bluetooth module uses the DDA14580 chip of Dialog. The chip has the characteristics of small size, low power consumption and the like, and meets the Bluetooth 4.2 standard. Built-in 16 MHz 32-bit processor Cortex-M0, and 84kB of ROM and 8KB of SRAM storage. Its transmit power is 3.4mA, the receive power is 3.7mA, and the current in the sleep mode is only 1.8μA.

4. Power management

The power consumption of the hardware part of the wearable acquisition equipment is mainly from the analog amplifier, the ADC, the MCU and the storage module, and the wireless transmission module. A larger proportion of which is from the storage module and the wireless transmission module. So, to reduce the power consumption of the hardware part, this design mainly starts from three aspects. The first is to select the hardware, and the power consumption of the whole system can be reduced by selecting the module with smaller power. Secondly, the time of the operation of the Bluetooth transmission module is shortened, and data compression is carried out on the acquired physiological parameters. [3] In the above physiological parameters, the electrocardiosignal is high in precision, the data volume is also the largest, and the accuracy of maintaining the data as much as possible during the compression process is also required. Another benefit of data compression is that storage space can be saved. The third is to start with the management of the external flash memory.

4.1 Hardware Selection

For the selection of hardware, this design as far as possible to select the low power consumption of the composition of the period. In the case of 3.3V power supply, the power consumption of the main control chip STM32L476ME is 3MW. The power consumption of the ADS1292R chip shared by ECG and respiration is 335μW of dual channels. The power consumption of the temperature

acquisition module LMT70 is 36μW. The acceleration sensor selects the low power mode with a power consumption of 3μw. The power consumption when Bluetooth is transmitted is 13.2MW, and the power consumption when sleeping is only 1.8μA. So when the system is in the mode of only collecting data and not sending out, the overall power consumption does not exceed 4mW. In the mode of Bluetooth sending data directly, the power consumption of the system is about 18 mw.

4.2 Transmission Mode

If the monitoring device does not have the wireless transmission module, only the collected physiological data is stored in the local storage at the time of operation, and after the recording is finished, the data is transmitted to the computer, and the portability and the real-time performance of the wearable device are lost. The transmission through the wireless transmission module is also divided into three modes of real-time transmission, timing transmission and control transmission. [4] The wireless transmission module of the real-time transmission mode is always in an active state and the power consumption is large. The timing transmission is to acquire enough data amount or a certain time to open the communication module to transmit data, the power consumption is small, and the real-time performance is central. And the control transmission is carried out according to the control of the user, the power consumption is small, but the using mode is more flexible. The design is mainly based on real-time transmission and control, because the focus of the two methods on the measurement of ECG data is different, and the time of real-time transmission is usually not too long, so the mode of control transmission is mainly used.

4.3 Storage Management

When the W25N01GV works in an active state, the current can reach 25mA, which is a great burden to the whole system, but only 10μA in the standby state. So flash chips can work intermittently. The whole system can collect the data of 1950Byte in one second, after compression is 450Byte, 27k data is generated in one minute, and the Flash chip can work for one minute and then write once, which takes a very short time. Can reduce the working current of about 25mA and greatly reduce the power consumption of the system.

5. Conclusion

This paper analyzes the characteristics of the pilot's flight mission in the air, and designs the multi-physiological parameter acquisition system of the pilot from the module. And the power consumption of the system is managed in three ways according to the use characteristics of the pilot, so that the overall power consumption of the system is small, the requirement of miniaturization and low power consumption is met, and the data in the last three days after the task is acquired and transmitted. The design of the pilot's physiological data acquisition system can effectively extract the physiological parameters such as ECG, respiration, body temperature and overload of the pilot, and guide the pilot's health management and flight training.

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